EurAsian Journal of BioSciences
Eurasia J Biosci 14, 2631-2641 (2020)

Heat resistance of introduced apple-tree varieties due to water status and seasonal development under arid conditions Of Mangistau

O.N. Kossareva [1*], D.N. Zharassova [1], N.A. Tolep [1]

[1] Mangyshlak Experimental Botanical Garden, Republican State Enterprise of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan, Aktau city, KAZAKHSTAN
*Corresponding author: O.N. Kossareva

Abstract
Excess heat has a negative effect on the growth and development of fruit plants, their productivity, so the success of introduction under conditions with a hot climate is determined by the plants resistance to overheating. The article presents for the first time the results of the heat resistance study of 10 introduced apple-tree varieties in seasonal dynamics due to their water content, transpiration rate and seasonal development. It was found that the heat resistance varied in different varieties and changed during the growth, decreasing in August-September in all varieties. Maximum values of water content in the leaves was observed in May and minimum in August-September. The maximum transpiration rate was from June to August, depending on variety. High heat resistance, water content and low transpiration rate were observed in all varieties at the end of May, against the background of a drop in the growth rate of shoots. At the completion time of shoot growth and the beginning of fruit ripening, the water content decreased in all varieties, transpiration rate varied in different directions, and heat resistance decreased in all varieties except the most stable ones (Stolovka, Renet Burkhardta). After fruit ripening and shoots lignification, water content, transpiration rate and heat resistance decreased in all varieties. The most productive varieties were characterized by high heat resistance.
The work was carried out on the topic of the Grant Project “Introduction of prospective apple-tree varieties for introduction into culture in the arid regions of West Kazakhstan”.

Keywords: apple-tree, varieties, introduction, arid conditions, heat resistance, water content, transpiration rate, phenological phases, productivity

Kossareva ON, Zharassova DN, Tolep NA (2020) Heat resistance of introduced apple-tree varieties due to water status and seasonal development under arid conditions Of Mangistau. Eurasia J Biosci 14: 2631-2641.

INTRODUCTION

Mangyshlak Experimental Botanical Garden is located on the Mangyshlak half-island, in the middle deserts of Eurasia. The climate of Mangystau is distinctly continental, with a lack of moisture throughout the growing season. The average annual air temperature was +9.6 - +11.5 ^{0}C; the absolute minimum air temperature was -34 ^{0}C (the last 40 years were characterized by a rather warm winter season, minus air temperature was not observed earlier than December and later than February, for a short time, and did not fall below -18 ^{0}C), the absolute maximum air temperature rose to + 47 ^{0}C; the average annual precipitation was 107–180 mm; snow cover in winter season is practically absent. Frequent winds with an average annual speed of 4.6 m/s are typical, the maximum speed is 30 m/s (at a speed of more than 10-12 m/s, there are dust storms).

The soils are brown, gray–brown and desert, characterized by a high degree of salinization, as well as close bedding to the surface of hard formations (Sarmatic lime-stones, etc.). Vegetation is typically desert, with a predominance of dwarf semishrub saltworts and wormwoods, and with ephemeral plants and ephemeroids in spring (Borovskiy, 1974; Hamzeheinejad, & Pal,2016).

To overcome unfavorable environmental factors, a special methods of introduced species growing and maintenance have been developed (Kossareva, 2012).

SUBJECTS AND RESEARCH METHODS

The subjects of research were 10 varieties of Apple-tree zoned in Kazakhstan (Asya, Voshod, Zailiyskoe, Zolotoe prevoshodnoe, Kandil-sinap, Mantet, Renet Burkhardta, Saltanat, Stolovka, Florina). Nursery plants

Received: October 2019
Accepted: April 2020
Printed: August 2020

Table 1. Heat resistance of introduced apple-tree varieties in seasonal dynamics

Name of the varieties	No Browning of the leaf blade (% of samples) at 40 ^{0}C					Weak browning of the leaf blade (% of samples) at 50 ^{0}C				
	20.05	11.06	10.07	13.08	10.09	20.05	11.06	10.07	13.08	10.09
Asya	60	80	40	60	40	100	80	100	100	100
Voshod	80	60	20	40	40	80	100	100	100	100
Zailiyskoe	80	40	20	20	20	80	100	100	100	100
Zolotoe prevoshodnoe	100	60	20	40	40	60	100	100	100	100
Kandil-sinap	80	60	40	20	20	80	100	100	100	100
Mantet	80	100	80	80	40	80	60	80	80	100
Renet Burkhardta	100	80	60	80	60	60	80	80	80	100
Saltanat	80	100	60	40	40	80	60	100	100	100
Stolovka	100	100	80	80	60	60	60	80	80	100
Florina	80	60	60	40	40	80	100	100	100	100

Name of the varieties	Browning of the leaf blade of more than 50% (% of samples) at 60 ^{0}C					Solid browning of the leaf blade (% of samples) at 70 ^{0}C				
	20.05	11.06	10.07	13.08	10.09	20.05	11.06	10.07	13.08	10.09
Asya	60	40	100	100	100	20	0	40	20	60
Voshod	60	60	60	80	100	20	40	20	20	60
Zailiyskoe	80	80	80	60	60	80	20	60	40	60
Zolotoe prevoshodnoe	40	60	100	80	100	20	60	20	40	60
Kandil-sinap	80	100	80	80	80	40	20	40	40	80
Mantet	40	0	60	60	80	20	0	0	20	60
Renet Burkhardta	40	20	40	60	60	20	20	20	20	60
Saltanat	60	40	100	100	100	20	0	40	40	60
Stolovka	40	40	20	80	80	0	0	20	20	40
Florina	40	60	80	100	80	20	40	20	40	60

of these varieties implanted on Sivers apple-tree were imported from Issyk Tree Nursery (Almaty city) and simultaneously bed out on a specially prepared plot in early April 2010. Soil preparation consisted in removing of the salinized higher slice of potting soil, then planting holes with dimensions of 1.5 x 2.0 meters and 1 meter deep were filled with a specially prepared substrate (a mixture of nonsaline sandy soil with manure and sawdust). The distance in the rows was 3 meters and 5 meters in the inter rows (interplant), canopy forming is free. A drip irrigation system was used for watering, consisting of a main pipeline, vent lines, vertical clarifying filters and two micro-irrigators per tree. During the growing season (from May to September), up to 25 waterings were carried out, the watering rate was 325 m^3/ha, and the irrigation rate was 8125 m^3/ha. Antecedent soil water varied from 70 to 75%.

The work was performed during 2019, the phenological observations were carried out according to established procedures (Dorfman, et al., 1991). productivity was determined by weight method (the average weight of fruits per tree out of 5 trees of each variety). Heat resistance was determined by direct laboratory method (according to F.F. Matskov, taking into account recommendations for fruit crops). (Khalin, 1973). Leaves samples were collected once a month from May to September in 5-fold replication. By the absence of browning or different degrees of each variety leaves browning at a specific heating temperature, the heat resistance of each variety was estimated, taking into account the indicators of more than 50% of the samples. Heat resistance was compared with water content and leaves transpiration rate, determined simultaneously with heat resistance, taking into account the growth phases and varieties development. Water content was determined by weight method (by drying the leaves to a constant weight at a temperature of 100-105 ^{0}C in five-fold replication), the transpiration rate – according to A.A. Ivanov .(Viktorov, 1991). To characterize weather conditions, a data from the local weather station was used. Statistical analysis of the results was carried out according to N.L. Udolskaya (Udolskaya, 1976). and G.F. Lakin .(Lakin Biometrics, 1990).

RESULTS

Heat resistance. The results of apple-tree varieties heat resistance determination in seasonal dynamics are presented in **Table 1**. When heated to 40 ^{0}C in May (20.05), all varieties showed no leaves browning (more than half of the samples), and the varieties of Zolotoe prevoshodnoe, Renet Burkhardta, Stolovka did not have browning in all samples (100%). Thus, all varieties were resistant to temperatures of 40 ^{0}C in May. In June (11.06) at a temperature of 40 ^{0}C, the leaves were not damaged in 9 varieties (Zailiyskoe variety was slightly damaged). In July (10.07), there was a sharp decrease in resistance to 40 ^{0}C heating (**Fig. 1**), half of the varieties showed a weak leaves browning (see **Table 1**). The absence of leaf blade's browning was recorded in the varieties of Mantet, Stolovka, Renet Burkhardta, Saltanat, Florina. Only 4 varieties had no browning of the leaf blade in August (13.08) – Mantet, Burkhardt Queen Apple, Stolovka, Asya (wherein the number of undamaged samples in the varieties Asya, Voshod, Zolotoe prevoshodnoe, Renet Burkhardta were higher than in July). In the Mantet, Stolovka, Zailiyskoe varieties, the percentage of leaves samples browning was the same in July and August.

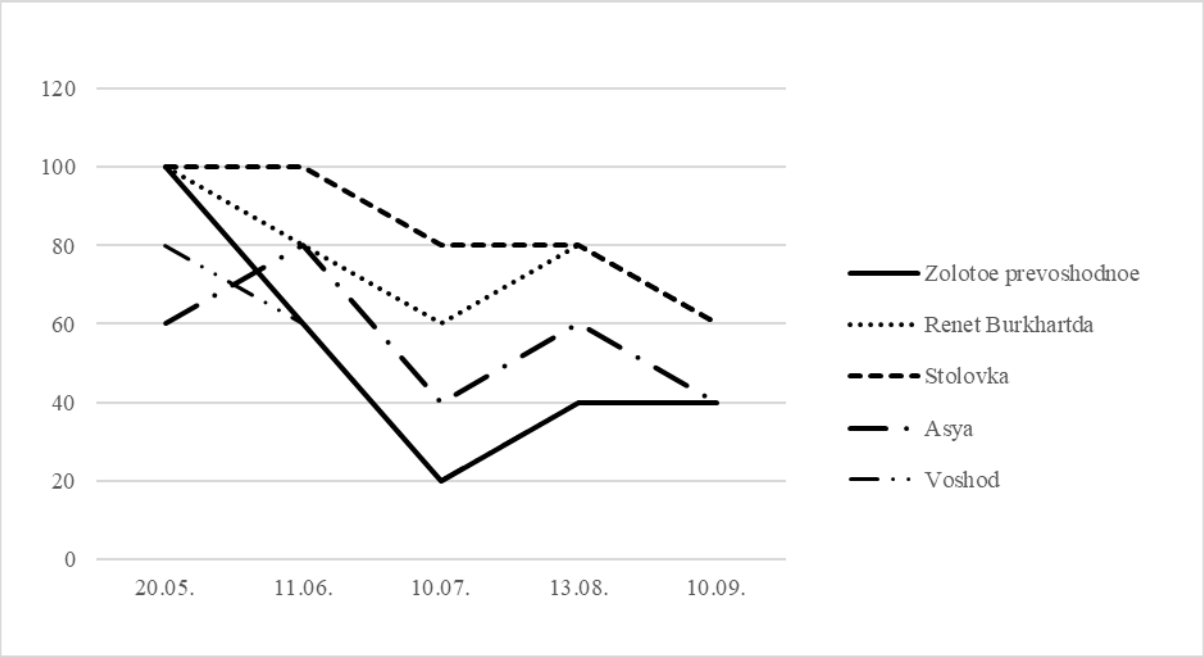

Fig. 1. Heat resistance dynamics of apple-tree varieties when heated up to 40 ^{0}C

Only 2 varieties did not show any leaves damages - Renet Burkhardta and Stolovka. Thus, the leaves resistance of the apple-tree varieties to heating up to 40 ^{0}°C changed during the growing season, decreasing by the end of the growth in most varieties, i.e. in May and June, heat resistance was the highest in all varieties; since July, a heat resistance decrease was in most varieties. Renet Burkhardta and Stolovka were most resistant when heated up to 40 ^{0}C during the entire growing season. In Zolotoe prevoshodnoe variety, the high heat resistance in May - June significantly decreased in July and remained low in August and September, as in Voshod and Kandil-sinap varieties. The heat resistance in Saltanat and Florina varieties began to decrease in August, in Mantet variety, it began to decrease in September. The Zailiyskoe variety had lowest heat resistance.

When heated up to 50 ^{0}C, all varieties and samples showed weak browning of the leaf blade during the entire growing season, in other words there were no varietal and seasonal differences in the resistance degree to heating at 50 ^{0}C (see **Table 1**).

When the leaves were heated to 60 ^{0}C, both weak browning and browning of more than 50% of the leaf surface were recorded. Differences in the heat resistance of varieties between themselves and in seasonal dynamics were revealed again (see **Table 1**). Zolotoe prevoshodnoe, Mantet, Renet Burkhardta, Stolovka, Florina varieties had a weak leaves browning in May, the other varieties had browning of more than 50% of the leaf surface, i.e. they were non-resistant when heated up to 60 ^{0}C. Mantet, Renet Burkhardta, Stolovka, Saltanat and Asya varieties were more resistant when heated up to 60 ^{0}C in June, and they had

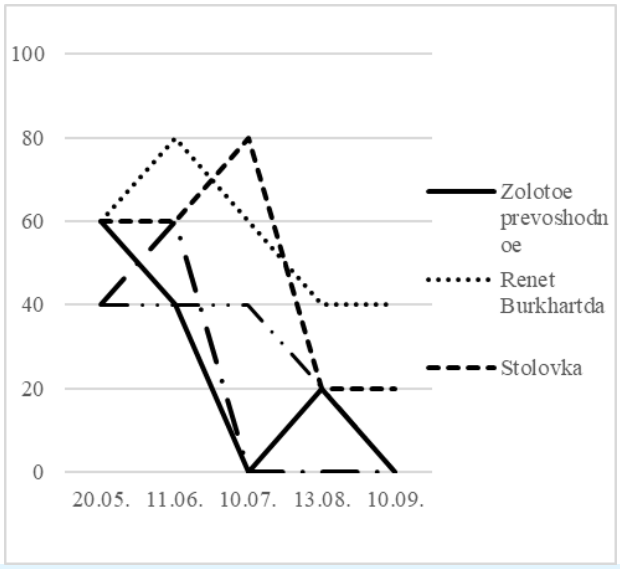

Fig. 2. Heat resistance dynamics of apple-tree varieties when heated up to 60^{0}C

a weak browning of the leaf blade. The remaining 5 varieties showed browning of more than 50% of the leaf surface. In July, a weak browning of the leaf blade was recorded only in Renet Burkhardta and Stolovka varieties, the other varieties showed browning of more than 50% of the leaf surface, i.e. in July, the heat resistance decreased in 8 varieties. In August, there was a sharp decrease in resistance to heating up to 60 ^{0}C (**Fig. 2**), all varieties showed browning of more than 50% of the leaf surface, which was observed in September.

Thus, when heated to a temperature of 60 ^{0}C, the most resistant varieties were Renet Burkhardta and Stolovka, in which browning of more than 50% of the leaf

Table 2. Water content of leaves in the seasonal dynamics (%)

Name of plants	20.05	11.06	10.07	13.08	10.09
Asya	60.5±2.2	60.3±1.0	53.4±8.0	45.6±3.7	48.3±4.0
Voshod	67.0±0.9	61.9±1.4	61.1±8.5	53.2±6.1	49.8±3.5
Zailiyskoe	56.8±1.3	54.6±1.7	54.5±6.7	50.6±9.7	50.2±2.2
Zolotoe prevoshodnoe	59.9±3.5	57.8±2.5	56.1±1.1	52.0±3.0	49.0±2.6
Kandil-sinap	62.1±2.0	56.9±1.4	54.8±2.4	65.2±13.5	49.4±4.3
Mantet	61.5±3.3	60.5±1.8	53.2±2.7	49.7±2.8	48.2±2.5
Renet Burkhardta	59.6±1.4	56.7±1.4	52.6±3.3	48.4±3.5	49.7±2.4
Saltanat	64.3±5.9	59.1±3.2	57.1±2.6	49.2±5.5	49.2±2.9
Stolovka	62.0±1.7	62.3±2.0	53.5±1.5	52.5±8.4	49.8±3.5
Florina	62.8±5.9	60.1±1.9	54.6±1.7	48.8±5.1	51.1±3.2

surface was observed only in August – September. In May – June, the Mantet, Zolotoe prevoshodnoe, Florina, Asya, Saltanat varieties were also resistant to heating up to 60 ^{0}C. Low heat resistance when heated up to 60 ^{0}C was observed in Zailiyskoe, Kandil-sinap and Voshod varieties during the entire growing season. In general, the heat resistance was higher in May and June in half of the varieties, in July - in 2 varieties, in August – September, the heat resistance decreased, and browning of more than 50% of the leaf surface was observed in all varieties.

When heated up to 70 ^{0}C, there was mainly browning of more than 50% of the leaf surface from May to August. Solid browning of the leaf blade was observed in May and July in Zailiyskoe variety, in June - in Zolotoe prevoshodnoe variety.

In September, solid browning of leaf blades was observed in all varieties except Stolovka variety. Thus, solid browning of the leaf blade when heated up to 70^{0}C was registered at the end of the growing season. Stolovka variety was the most heat-resistant when heated up to 70^{0}C.

Taking into account the results of the leaves heating from 40 to 70^{0}C, the most heat-resistant varieties are Stolovka and Renet Burkhardta, whose heat resistance is 60^{0}C from May to July. They are adjoined by Mantet, Saltanat and Asya varieties, whose heat resistance of 60^{0}C was observed from May to June, and decreased in the following months. In Zolotoe prevoshodnoe and Florina varieties, the high heat resistance of leaves of 60^{0}C is recorded only in May. Zailiyskoe, Kandil-sinap, Voshod varieties proved to be the least resistant to high temperature, in which more than 50% of the leaf blade browning was observed when heated up to 60^{0}C.

Water content. A number of researchers point to a close relationship between water content and transpiration rate (TR) with the resistance of apple-tree varieties to overheating [9 - 12]. **Table 2** shows the water content of apple-tree leaves, which was determined simultaneously with the heat resistance.

The highest water content of leaves was observed in all varieties on May 20 (the beginning of measurements), and the lowest was in August-September. The highest water content in the leaves was observed in Voshod (67, 0±0.9), Saltanat (64.3±5.9), and Florina (62.8±5.9) varieties. The lowest water

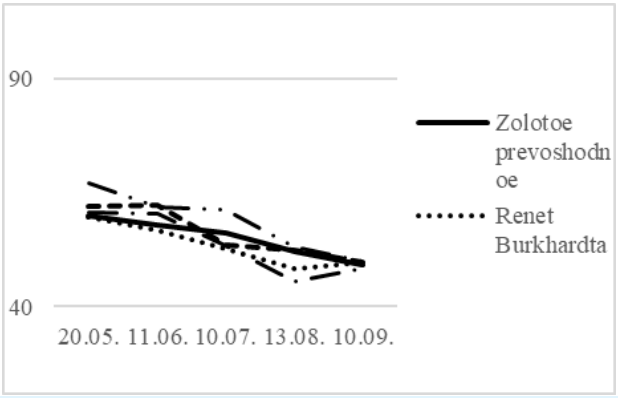

Fig. 3. Water content of some apple-tree varieties in seasonal dynamics

content of leaves was observed in August (in the Asya, Renet Burkhardta, Florina varieties) and in September (in other varieties) in the range from 45.6±3.7 (Asya) to 51.1±3.2 (Florina). The water content of leaves generally decreased during the growing season from May to September (**Fig. 3**).

Seasonal dynamics of water loss by leaves is shown in **Table 3**. In June (11.06), apple-trees lost 2 - 8% of water from the May indicators, except for the Asya and Stolovka varieties, the water content leaves of which remained at the May level. In July (10.07) the water loss by leaves increased up to 12 - 14 % in most varieties, with the exception of Voshod (water loss is lower than in June) and Zailiyskoe varieties (water loss is the same as in June. In August (13.08), water loss increased up to 19 - 25% (exception is Kandil-sinap variety). In September (10.09), water loss by leaves increased in Voshod, Zailiyskoe, Zolotoe prevoshodnoe, Kandil-Sinap, Mantet and Stolovka varieties (from 12 to 26%).

In Asya, Renet Burkhardta and Florina varieties, the water loss decreased in September compared to August indicators, while Saltanat variety remained at the same level.

Thus, the heat resistance decreased simultaneously with the decrease in water content of leaves from May to September, but in accordance with the characteristics of each particular variety. For example, in the Asya variety, the heat resistance of the leaves was quite low in May, and in June, when the water content was the same as in May, the heat resistance reached a maximum value of

Table 3. Water content dynamics of introduced apple-tree varieties

Name of the variety	Water content of May 20 (%)	Water loss (% of May's value)			
		11.06	10.07	13.08	10.09
Asya	60.5±2.2	0	12	25	20
Voshod	67.0±0.9	8	7	21	26
Zailiyskoe	56.8±1.3	4	4	11	12
Zolotoe prevoshodnoe	59.9±3.5	4	6	13	18
Kandil-sinap	62.1±2.0	8	12	0	21
Mantet	61.5±3.3	2	14	19	21
Renet Burkhardta	59.6±1.4	5	12	19	17
Saltanat	64.3±5.9	8	11	24	24
Stolovka	62.0±1.7	0	14	15	20
Florina	62.8±5.9	4	13	22	19

Table 4. Transpiration rate value from May to September (from 9^{30} to 11^{00} hours)

Date	Weather factors		Transpiration rate (T_R) (mg/g of raw leaves weight per hour)				
	air temperature ^{0}C	RH %	Asya	Voshod	Zailiyskoe	Zolotoe prevoshodnoe	Kandil-sinap
20.05.19	+25	26	60±6.2	83±6.8	59±4.2	107±7.1	81±14.9
11.06.19	+30	35	210±6.1	223±3.0	158±8.7	136±2.2	141±5.8
10.07.19	+31	36	276±4.6	212±7.4	208±7.1	295±1.7	192±7.5
13.08.19	+22	57	179±4.5	322±7.6	74±8.9	38±4.6	148±6.2
10.09.19	+14	56	84±5.0	179±2.2	68±3.0	41±1.4	119±6.3

Date	Weather factors		Transpiration rate (T_R) (mg/g of raw leaves weight per hour)				
	air temperature ^{0}C	RH %	Mantet	Renet Burkhardta	Saltanat	Stolovka	Florina
20.05.19	+25	26	62±13.0	69±7.1	80±9.3	72±2.9	145±13.1
11.06.19	+30	35	298±0.6	243±5.2	132±3.6	222±8.4	162±9.7
10.07.19	+31	36	245±9.8	258±2.7	120±4.8	195±2.1	127±5.0
13.08.19	+22	57	96±4.7	304±5.8	43±6.9	169±6.8	81±7.4
10.09.19	+14	56	56±8.9	131±13.8	48±6.7	99±6.5	80±0.9

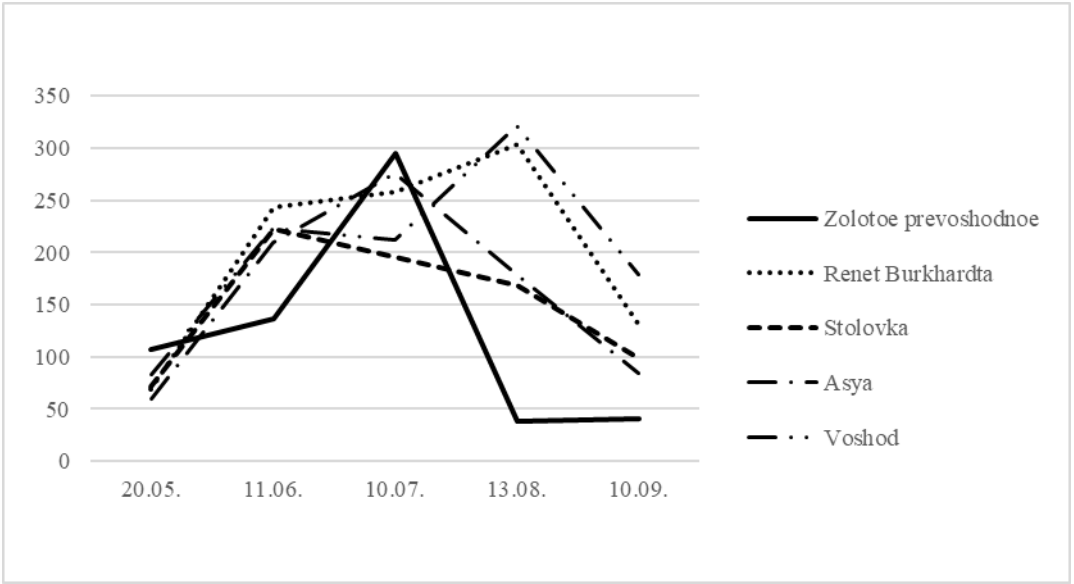

Fig. 4. Transpiration rate of some apple-tree varieties in seasonal dynamics

60^0C, and in July, with the loss of 12% of water, the heat resistance decreased sharply.

In the most resistant varieties (Stolovka and Renet Burkhardta) to overheating, the heat resistance fell with a water loss of 15 - 19% according to the May's indicators, in Voshod, Kandil-sinap, Saltanat varieties – with a loss of 8%, in the least heat-resistant variety (Zailiyskoe) – with a loss of 4% of the leaves water content in May (see **Tables 1** and **3**).

The **transpiration rate** during the determination of leaves heat resistance is shown in **Table 4**.

At the beginning of measurements (May 20), the transpiration rate value (TR), carried out in the morning, simultaneously with heat resistance measurements and averaged 59±4.2 – 83±6.8, mg/g per hour, i.e. it was quite low. In Zolotoe prevoshodnoe and Florina varieties, it was significantly higher (107±7.1 – 145±13.1 mg/g per hour). The transpiration rate highest value during the entire growing season was observed on August 13 in Voshod (322±7.6 mg/g per hour) and Renet Burkhardta varieties (304± 5.8 mg/g per hour) (**Fig. 4**).

Table 5. Transpiration rate dynamics (T_R) of introduced apple-tree varieties

Name of the variety	T_R of May 20 (mg/g per hour)	The T_R value (% of the May value)			
		11.06	10.07	13.08	10.09
Asya	60±6.2	350	460	300	140
Voshod	83±6.8	270	260	390	220
Zailiyskoe	59±4.2	270	350	130	120
Zolotoe prevoshodnoe	107±7.1	130	280	40	40
Kandil-sinap	81±14.9	170	240	180	150
Mantet	62±13.0	480	400	160	90
Renet Burkhardta	69±7.1	350	370	440	190
Saltanat	80±9.3	170	150	50	60
Stolovka	72±2.9	310	270	240	140
Florina	145±13.1	110	90	60	60

On June 11, TR increased in all varieties in the range from 130 to 480% compared to the May's values (**Table 5**), while in the Mantet, Saltanat, Stolovka and Florina varieties it reached the maximum values for the entire observation period. The TR high value was also observed in June in Renet Burkhardta, Voshod and Asya varieties. At the same time, the heat resistance of these varieties has also increased (with the exception of Florina and Voshod varieties).

On July 10, TR decreased in half of the varieties by 20-80% compared to the June values (in the Sunrise variety – by 10%). In the remaining 5 varieties, TR continued to increase, and in the Asya, Zailiyskoe, Zolotoe prevoshodnoe and Kandil-sinap varieties reached the maximum values for the entire observation period. At the same time, the resistance to heating up to 40^0C significantly decreased in all varieties. When heated to 60^0C, Browning of more than 50% of the leaf blade was absent only in the Stolovka and Renet Burkhardta varieties.

On August 13, it sharply decreased in Zolotoe prevoshodnoe, Saltanat and Florina varieties (amounting to 40 - 60% of the May indicators), a significant TR decrease was also observed in the Zailiyskoe, Mantet, Asya varieties. In general, a TR decrease in early August was observed in 8 varieties. A significant TR increase was observed only in Renet Burkhardta and Voshod varieties, which reached the maximum values for the entire growing season (390 and 440% of the May indicators). At this time, the heat resistance of Renet Burkhardta and Asya varieties increased when heated to 40^0C, Mantet and Stolovka varieties remained unchanged, and in the other varieties, the heat resistance was decreased. When heated to 60^0C, all varieties showed browning of more than 50% of the leaf surface, i.e. heat resistance decreased even in the most resistant varieties.

At the beginning of September (10.09) TR decreased in all varieties, with the exception of the Saltanat variety, in which it increased slightly, although it remained below the May indicators. In Zolotoe prevoshodnoe and Florina varieties, it did not change in comparison with the August indicators and was only 40 – 60% of the May values. In comparison with August indicators, it fell sharply in the Asya, Voshod, Renet Burkhardta and Stolovka varieties, but it was higher than at the beginning of the growing season. At the same time, the heat resistance decreased even when heated to 40^0C in all varieties, except for the Stolovka variety. When heated to 60^0C, all varieties showed Browning of more than 50% of the leaf surface.

Thus, during the growing season, TR increased sharply in June for all varieties, in July it decreased for half of the varieties (it increased for the rest), in August it decreased for 8 varieties, in September it decreased or remained at the same level for almost all varieties. The TR maximum values were observed in the varieties Mantet, Saltanat, Stolovka, Florina in June, in the Asya, Zailiyskoe, Zolotoe prevoshodnoe, Kandil-sinap varieties in July, and in Voshod and Renet Burkhardta in August. Transpiration rate seasonal dynamics of apple-tree varieties appeared as a unimodal curve, with a maximum in June, July or August. In addition, all varieties registered a significant TR increase in early June, due to a sharp increase in air temperature.

The transpiration rate amount is not directly related to heat resistance, although in some varieties the TR increase was accompanied by an increase in heat resistance. So, in June, the TR increase in Mantet, Saltanat, Stolovka, Renet Burkhardta, Asya varieties was accompanied by an increase in heat resistance up to 60^0C. On the contrary, in July, the TR increase to the maximum values in the Asya, Zailiyskoe, Zolotoe prevoshodnoe, Kandil-sinap varieties was accompanied by a significant decrease in heat resistance even when heated to 40^0C. In August, the TR increase to the maximum values was observed in Renet Burkhardta and Voshod varieties, while the heat resistance of the varieties increased when heated to 40^0C and decreased sharply at 60^0C.

Seasonal development and dynamics of physiological processes. The main growth phases and development of apple-tree varieties are shown in **Table 6**. As follows from **Table 6**, the leaf ripening completion (L^3) in all varieties was observed from April 12 to 25, and in May 20 (beginning of experiments), the grow shoots were continued in the apple-tree varieties (Sh^1-Sh^2) and fructification. The most intensive growth of shoots was observed until May 15, after which a drop in the growth rate of most varieties was recorded. Thus, high heat resistance, water content and low TR of leaves in all varieties were observed against the background of

Table 6. Main phenological dates of introduced apple-tree varieties in 2019

Name of the variety	Onset dates of apple-tree varieties phenological phases									
	L[1]	L[3]	Sh[1]	Sh[2]	C[4]	C[5]	Fr[3]	Fr[3]	O[2]	L[4]
Asya	30.03	25.04	30.04	03.06	24.04	03.05	18.08	25.08	09.08	12.10
Voshod	27.03	22.04	30.04	17.06	24.04	03.05	12.08	01.09	15.08	13.10
Zailiyskoe	27.03	12.04	29.04	17.06	29.04	03.05	09.08	22.08	10.08	11.10
Zolotoe prevoshodnoe	27.03	15.04	30.04	24.06	25.04	03.05	12.08	28.08	10.08	13.10
Kandil-sinap	27.03	24.04	29.04	17.06	29.04	06.05	12.08	29.08	10.08	13.10
Mantet	29.03	16.04	30.04	13.06	24.04	03.05	18.07	05.08	12.08	13.10
Renet Burkhardt a	27.03	16.04	26.04	03.06	25.04	02.05	18.07	02.08	10.08	13.10
Saltanat	30.03	25.04	26.04	17.06	25.04	06.05	18.08	28.08	10.08	17.10
Stolovka	01.04	24.04	30.04	17.06	24.04	02.05	09.07	02.08	14.08	17.10
Florina	26.03	25.04	30.04	17.06	25.04	06.05	12.08	25.08	14.08	17.10

a drop in the shoots growth rate at high temperature and low humidity (+ 27^{0}C and 27%). During this period, Zolotoe prevoshodnoe, Renet Burkhardta, Stolovka, Mantet, Florina varieties showed a slight browning of the leaf blade when heated to 60^{0}C, and a browning of more than 50% of the leaf blade in the other varieties (see **Table 1**, **Fig. 1**).

On June 11, the growth of shoots still continued in all apple-trees, except for Asya and Renet Burkhardta varieties, but the growth rate was low. At the same time, the air temperature increased to +32^{0}C, humidity decreased to 35-39%. Leaves water content decreased by 2 - 8% (in Asya and Stolovka varieties remained unchanged), and TR sharply increased (see **Tables 4** and **5**). At this time, high heat resistance was observed in Mantet, Renet Burkhardta, Saltanat, Stolovka, Asya (see **Table 1**, **Figs. 1** and **2**), i.e. the heat resistance increased in the Asya and Saltanat varieties, and in Zolotoe prevoshodnoe and Florina varieties it significantly decreased, especially when heated to 60^{0}C. The heat resistance of leaves in the Zailiyskoe variety has fallen sharply (already when heated to 40^{0}C), as well as in Voshod, Kandil-sinap and Florina varieties (when heated to 60^{0}C).

In early July, before the experiments, the air temperature rose to 33^{0}C and it rained, so on July 10, the humidity increased to 67% with a slight decrease in the air temperature (26-31^{0}C). By this time, the growth of shoots (Sh^2) in all varieties had ended and fruit ripening continued, which was completed only in Stolovka variety (Sh^3) (see **Table 6**). Despite relatively more favorable conditions, leaves water content continued to decrease in all varieties by 6 - 14 % from the May level (Zailiyskoe variety remained at 4%), TR decreased in half of the varieties (Voshod, Mantet, Saltanat, Stolovka, Florina varieties), in the rest Asya, Zailiyskoe, Zolotoe prevoshodnoe, Kandil-sinap varieties, it increased and reached a maximum. The high heat resistance of the leaves (60^{0}C) were observed only in varieties of Stolovka and Renet Burkhardta. The heat resistance of Mantet, Saltanat, and Florina varieties remained quite high when heated to 40^{0}C, but fell to critical values at 60^{0}C.

When measured on August 13, a sharp decrease in air temperature to 24 – 19^{0}C was recorded, although the temperature increased to 34^{0}C on 10.08, and a dust storm followed by rain was observed on 11.08. The air humidity is increased to 40 to 66%, while there was a strong wester wind. Fruit ripening (Fr^3) was completed in all apple-trees, except for the Asya and Saltanat varieties, fruits drop (Fr^4) was recorded in Renet Burkhardta, Stolovka, Mantet varieties. Shoots lignification (Lign^2) was also observed. At the same time, leaves water content decreased sharply in all varieties (by 11 - 25% from the May level), except for Kandil–sinap variety. TR decreased in 8 varieties, and in Zolotoe prevoshodnoe, Saltanat and Florina varieties decreased to the minimum values for the entire growing season. In Voshod and Renet Burkhardta varieties, TR increased sharply and reached maximum values for the entire growing season. The heat resistance of leaves in August decreased in most varieties already when heated to 40^{0}C, the leaves were not damaged only in Renet Burkhardta, Stolovka, Mantet, Asya varieties. When heated to 60^{0}C, even the most heat-resistant varieties of Stolovka and Renet Burkhardta damaged more than half of the samples, i.e. the heat resistance was below 60 ^{0}C.

In September (10.09), after fruit drop (Fr^4) and shoots lignification (Lign^2) in all varieties, leaves water content decreased simultaneously with a decrease in air temperature from 26 to 14^{0}C and an increase in air humidity from 35 to 70%. There was also a drop in TR in all varieties (in Zolotoe prevoshodnoe, Saltanat and Florina varieties, the TR significantly decreased already in August and remained at that level in September). Heat resistance was the lowest for the entire growing season.

Thus, in the most heat-resistant varieties of Stolovka and Renet Burkhardta, the heat resistance reached 60^{0}C from May to July, and in August-September it decreased. Mantet, Saltanat, Asya varieties were resistant to a temperature of 60^{0}C in June, and Zolotoe prevoshodnoe and Florina varieties in May.

Taking into account the results of heating leaves from 40 to 70^{0}C, the most heat-resistant varieties are Stolovka and Renet Burkhardta; high heat-resistance is also noted in the Mantet, Florina, Golden, Saltanat varieties. Zailiyskoe, Kandil-sinap, Voshod varieties turned out to be less resistant to high temperature.

Productivity (yield) and fruit quality are the main characteristics of the varieties prospects. The productivity of apple-tree varieties in 2016 - 2019 is shown in **Table 7**.

Table 7. Productivity of apple-tree varieties (2016 - 2019)

Name of the variety	First fruitification (year)	Productivity (year)				Mean productivity (kg/tr)
		2016 (kg/tr)	2017 (kg/tr)	2018 (kg/tr)	2019 (kg/tr)	
Asya	2012	8.0	12.4	2.6	10.7	8.4
Voshod	2013	10.2	10.0	4.2	10.5	8.7
Zailiyskoe	2012	11.0	10.5	2.3	12.6	9.1
Zolotoe prevoshodnoe	2012	7.0	26.2	3.5	22.4	14.7
Kandil-sinap	2014	7.0	12.0	3.7	15.3	9.5
Mantet	2012	8.0	19.2	11.3	17.5	14.0
Renet Burkhardta	2012	8.7	17.0	7.7	19.7	13.3
Saltanat	2014	6.0	8.0	3.1	9.1	6.5
Stolovka	2014	11.0	18.8	13.0	19.3	15.5
Florina	2014	13.0	18.0	3.2	17.5	12.9

According to the mean productivity (for 4 years of observations), the best varieties were Stolovka, Zolotoe prevoshodnoe, Mantet and Renet Burkhardta, the low productivity was recorded in Saltanat, Asya, Voshod varieties. The fruitification periodicity was clearly expressed in Zolotoe prevoshodnoe, Renet Burkhardta, Kandil-sinap varieties. In Stolovka and Mantet varieties, the fruitification periodicity is practically absent; in the bad harvest 2018, they were characterized by rather high productivity (see **Table 7**). The most productive varieties were also characterized by high heat resistance (Stolovka, Renet Burkhardta, Zolotoe prevoshodnoe, Mantet).

RESULTS AND DISCUSSION

Excess heat has a negative effect on the growth and development of plants, the productivity value and the fruitification periodicity. The fruit crops reaction to high temperature is determined by their heat resistance .(Doroshenko, et al,. 2010). The variety should maximize the realization of biological and genotypic potentials in constantly changing environmental conditions, and have stable fruitification (Ivanenko, 2016). The ability of plants to withstand overheating is an important characteristic for a comprehensive assessment of fruit crop varieties drought-resistance (Kuznetsova, 2008). which also includes the overall water content and transpiration rate.

Changes in the dynamics of leaves water content in the summer period against the background of regularly changing growth and development phases make it possible to assess the adaptive capabilities of introduced species and the prospects for their introduction into culture (Yemelyanov, et al., 1992). In this work, the leaves water content fluctuations during the growing season were revealed, the maximum water content was observed mainly in May, and by the end of the growing season the water content was reduced to the minimum values. The leaves water content in different varieties varied from 67.0 - 56.8% at the end of May to 51.1 – 45.6% in August – September.

Transpiration is used to prevent overheating and reduce the temperature of plants. Pomaceous fruit are characterized by relatively high transpiration. The mechanism of resistance to drought in them is increased osmotic pressure and features of the leaves anatomical organization (Kuznetsova, 2008). At the same time, fruit plants are subjected to water stress as a result of a moisture lack in the soil, and due to increased transpiration in response to high temperatures and low humidity, even with optimal soil moisture (Kushnirenko, 1976). Overheating of plants can also occur under irrigation conditions, especially with drop irrigation, which does not optimize the micro-climate of the garden.(Doroshenko, et al,. 2010). The transpiration rate of the apple-tree, along with meteorological factors, is influenced by the biological characteristics of the variety. Transpiration is highly labile and depends on hydrothermic environmental factors (Krivoruchko, 1998). Under our conditions, a close correlation relationship has been established between the transpiration rate and the leaves water content of woody plants, as well as the reliability of the transpiration rate with relative humidity and air temperature (Imanbayeva, et al., 2019). In this work, it was found that the transpiration rate affects the heat resistance indirectly, through the water content of leaves. If, due to increased transpiration, the water content of leaves decreased to an individual value for each particular variety, then the heat resistance also fell. In varieties with low heat resistance, the drop value in water content compared to May's indicators was lower, in heat–resistant varieties it was higher. In the most resistant to overheating varieties Stolovka and Renet Burkhardta, the heat resistance decreased with a water content decrease to 15 - 19% of the total content in May.

In terms of heat resistance, the apple-tree occupies a middle position between the pear (high) and mountain ash (low heat resistance) (Kuznetsova, 2008). It was shown (Nenko, et al., 2015). that heat resistance varied in different varieties and varied from June to August, decreasing in most varieties by the end of the growing season. Under the conditions of Mangistau, the heat resistance was determined for 9 types of apple-tree (Kosareva, 1983) and 3 varieties of apricot (Imanbayeva, A et al., 2015). Damage to the leaf blade in apple-tree species began at a temperature of 52-53^{0}C, and the lethal damage was observed at 55-57^{0}C. In general, the heat resistance of apple-trees was higher than the heat resistance of apricots, approximately equal to the heat resistance of some types of pears and for 2-

3^0C lower than the heat resistance of almonds (Kosareva, 1983). In this work, it was found that light damage to the leaf blade when heated to 40^0C occurred in most varieties from July to September, and in the most heat–resistant varieties Stolovka and Renet Burkhardta, leaves were not damaged during the entire growing season. The light damage of leaf blade was observed when heated to a temperature of 50^0C in all varieties from May to September, the lethal damage was observed when heated to 60^0C in most varieties from May to September, in the most resistant varieties, the lethal damage of leaves began in June (Zolotoe prevoshodnoe, Kandil-sinap, Florina), July (Mantet) or in August (Stolovka, Renet Burkhardta).

The literature data on the water regime and heat resistance of some apple-tree varieties are comparable with our results. Zolotoe prevoshodnoe variety in drought-affected conditions of the Astrakhan region was characterized by increased heat resistance and fruitification periodicity (Ivanenko, 2016). The drought-affected conditions of summer periods negatively affected the fruits formation. The main mass of varieties was characterized by fruits below the average value (71-110 g). (Ivanenko, 2016). Under our conditions, the fruits weight of Zolotoe prevoshodnoe variety is even lower – from 67.4 to 91.4 g., although there are varieties with larger fruits (141.0-246.7 g. in Askar variety) .(Kosareva, et al., 2019). Under arid conditions of Astrakhan region, the apple-tree varieties have a fairly high water content of leaves (at the average of 44.2%) in July – August, at a temperature of 38 – 40^0C. Under our conditions, in July-August, the leaves water content of some apple-tree varieties fell to 45.6±3.7%. Zolotoe prevoshodnoe variety is selected as one of the 3 varieties that are most resistant to drought, while the variety has a low heat resistance .(Menshutina, 2016). In this work, it is noted that the heat resistance of the variety was higher in May – June, then it decreased. In Kyrgyzstan, the apple-tree leaves were damaged at a temperature of 42-48^0C, depending on the variety, and the lethal temperature for most varieties is 50 - 54^0C (Krivoruchko, 1998)., which is comparable to our data. The total water content of apple-tree leaves in Kyrgyzstan ranges from 55.8 to 68% depending on the variety, under our conditions from 67.0 ±0.9 % in spring and to 49.8 ±4.0 % in autumn for varieties with high leaves water content (Voshod). It is noted that in the spring, the water in the leaves is much more than in the autumn period (Krivoruchko, 1998), as under our conditions. Due to the leaves senescence, the amount of water in them was reduced. Zolotoe prevoshodnoe variety is also mentioned here among the most heat-resistant varieties. Under the conditions of Krasnodar territory (Doroshenko, et al., 2010). the water content of apple-tree leaves of Florina variety in June, regardless of soil maintenance method, was quite high and amounted to 58.4 - 65.6%, under our conditions, the leaves water content of Florina variety was 60.1±1.9 % in June. During the summer period, a gradual decrease in water content was recorded, associated with a weakening of water availability (Doroshenko, et al., 2010). The heat resistance determination of Florina variety showed that when the temperature increased to 50 - 60^0C, the plants suffered from overheating. At the same time, Florina variety is named among the most drought-resistant varieties (Doroshenko, et al., 2010). This work shows that Florina variety was resistant when heated to a temperature of 60^0C in May, but since June, there have been lethal damage to the leaf blade.

The growth and development phases of apple-trees, along with the biological characteristics of the variety, depend more on climatic factors (Krivoruchko, 1998). Under our conditions, it has been established that the difference in the phenological phase transit times for years is much larger in one variety than the difference between different varieties for one year (Kosareva, et al., 2019). The growth of shoots was observed during the periods of the highest water content of shoots and leaves, especially from the beginning of May to the middle of June. The fruits ripeness stage also depends on the weather conditions of the year, (Krivoruchko, 1998), under our conditions, fruits ripening generally shifted to earlier dates, but the sequence (from summer to autumn varieties) was kept up (Kosareva, et al. 2019).

The most productive varieties are identified - Stolovka, Zolotoe prevoshodnoe, Mantet, Renet Burkhardta. Which, as revealed in this work, are also the most heat-resistant. In addition, they were characterized by low variation coefficients of phenological dates, i.e. they were more resistant under local conditions (Kosareva, et al,. 2019).

CONCLUSION

The heat resistance of introduced apple-tree varieties varied among different varieties and varied from May to September, generally decreasing by the end of the growing season.

When heated to 40^0C, the leaf blade was slightly damaged in most varieties from July to September and was not damaged in the Stolovka and Renet Burkhardta varieties during the entire growing season. At 50^0C, there was light damage to the leaf blade in all varieties from May to September. At 60^0C, the lethal damage to the leaf blade (Browning of more than 50% of the leaf blade) was observed from July to September in most varieties. At 70^0C, the lethal damage to the leaf blade was observed in all varieties from May to September, the solid browning of the leaf blade was in September (except for Renet Burkhardta variety).

The leaves water content of apple-tree varieties varied during the growing season, the maximum water content was observed in May, and by the end of the growing season, the water content decreased to minimum values (from 67.0±0.9 – 56.8±1.3% at the end

of May to 51.1±3.2 – 45.6±3.7 % in August – September). When the water content of the leaves was reduced to an individually significant value for each variety, the heat resistance also fell. In the most resistant to overheating varieties Stolovka and Renet Burkhardta, the heat resistance decreased with a water content decrease to 15 - 19% of the total content in May.

The amount of transpiration rate affected the heat resistance indirectly, through the amount of leaves water content. If the increase in transpiration rate did not lead to an individual decrease in water content for a particular variety, then the heat resistance increased.

High heat resistance, water content and low transpiration rate were observed in all varieties at the end of May, against the background of a drop in the growth rate of shoots. At the completion time of shoot growth and the beginning of fruit ripening, the water content decreased in all varieties, transpiration rate varied in different directions, and heat resistance decreased in all varieties except the most stable ones (Stolovka, Renet Burkhardta). After fruit ripening and shoots lignification, water content, transpiration rate and heat resistance decreased in all varieties.

Heat resistance reached 60^0 in Stolovka and Renet Burkhardta varieties from May to July, in Mantet variety in May – June, in Zolotoe prevoshodnoe and Florina variety in May. The most productive Stolovka, Zolotoe prevoshodnoe, Mantet and Renet Burkhardta varieties was characterized by a high heat resistance.

REFERENCES

Borovskiy, V.M.(1974). Soils of Mangyshlak half-island.- Alma-Ata city: Kainar, 1974. p. 268

Dorfman, Y. A., Yukht, I. M., Levina, L. V., Polimbetova, G. S. S., Petrova, T. V., & Emel'yanova, V. S. (1991). Oxidation of phosphine and arsine by metal complexes and free and bound oxygen. *Russian Chemical Reviews*, *60*(6), 605.

Doroshenko, T.N., Zakharchuk, N.V., Ryazanova, L.G.(2010). Adaptive potential of fruit plants of South of Russia. - Krasnodar- p. 131

Hamzeheinejad, N., & Pal, H. (2016). Mobile Food Consumption Monitoring Application. Journal of Food Technology Research, 3(2), 88-98.

Imanbayeva, A.A., Belozerov, I.F.(2019). Some physiological indicators of the woody plants resistance under the arid conditions of Mangistau desert. - Horticulture and grape culture. Physiology and biochemistry Series. (3). p. 13 - 26.

Imanbayeva, A.A., Kossareva, O.N., Zharassova, D.N.(2015). Water relationships features of introduced apricot varieties in Mangistau. - "Izvestiya" Journal of NAS RoK, ser. "Biology and medicine", vol.1, #307 48 – 58.

Ivanenko, Ye.N.(2016). Study results of the apple-tree collection in the Pre-Caspian Research Institute of arid agriculture. Current trends of agriculture development: materials of international applied science conference. Pre-Caspian Research Institute of Arid Agriculture Federal State Funded Research Institution, Agricultural Multiversity Regional Fund. P. 639 - 642.

Khalin, G.A.(1973). To the physiological diagnosis method of fruit crops heat resistance. Estimation methods of plant resistance to difficult environments. L., p. 92-94

Kosareva, O. N., & Dinova, G. E. (2019). Seasonal development of introduced apple-tree varieties under arid conditions of Western Kazakhstan. *EurAsian Journal of BioSciences*, *13*(2), 717-727.

Kosareva, O.N.(1983). Heat resistance of apple-tree introduced species under conditions of Mangyshlak half-island "Izvestiya" Journal of Academy of Science of Kazakh SSR (ser. of biolog.), #2, - p. 78-79.

Kossareva, O.N.(2012). Agricultural Technology Features of fruit plants growing in

Krivoruchko, V.P.(1998). Ecological and biological underpinnings of apple gardens productivization of Northern Kyrgystan. - Extended abstract of dissertatio ...Doctor of biological sciences Bishkek, p. 36.

Kushnirenko, M.D.(1976). Physiology of irrigated apple and peach trees / M.D. Kushnirenko, G.P. Kurchatova, Ye.M. Bondar et al. - Kishnev: Shtiintsa, p. 233.

Kuznetsova, N.V.(2008). Pomaceous fruits resistance to abiotic stress factors. Extended abstract of dissertatio ... M Agr / Michurinsk State Agriculture University Michurinsk, 2008. p. 23.

Lakin Biometrics, G.F.(1990). Moscow: Higher school, p. 352.

Mangistau. Introduction, biodiversity conservation and green construction in arid regions (materials of the international scientific conference, dedicated to the 40th anniversary of the Mangyshlak Experimental Botanical Garden) - Aktau city, p. 76 - 80.

Menshutina, T.V.(2016). Resistance of new introduced apple-tree varieties to stress factors of the summer period of Astrakhan region. Current trends of agriculture development: materials of international applied science conference of Pre-Caspian Research Institute of Arid Agriculture Federal State Funded Research Institution, Agricultural Multiversity Regional Fund. P. 642 - 645.

Nenko, N.I., Kiseleva G.K., Ye.V.(2015). Ulyanovskaya. Adaptation of apple-tree varieties of various origin to the high temperatures of summer period. A new ground in science: development prospects. #1 (3). P. 13 - 15.

Ozherelyeva, Z.Ye., Krasova, N.G., Galasheva, A.M.(2013). Water relationships study of apple-tree varieties in summer period due to their drought-resistance and heat resistance. Scientific and technical achievements of AIC. #1. P. 17 – 19.

Ozherelyeva, Z.Ye., Krasova, N.G., Galasheva, A.M.(2018). Study of apple-tree resistance under conditions of heat shock. Modern horticulture. #2 (26). p. 1 - 7.

Udolskaya, N.L.(1976). Methods of biometric calculations. - Alma-Ata: Science, p. 45

Viktorov, D.P.(1991). Laboratory course on plant physiology. Voronezh, p. 146

Yemelyanov, L.G., Ankund, S.A.(1992). Water exchange and plant stress resistance. Moscow: Science and Technology Publication, p. 144.